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**Cawnpore-American Cotton: An Account of
Experiments in its Improvement by Pure Line
Selection and of Field Trials, 1913-1917**

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Cawnpore-American Cotton : An Account of Experiments in its Improvement by Pure Line Selection and of Field Trials, 1913-17,

[Received for publication on 31st October, 1918.]

I. Introductory.

IN the *Agricultural Journal of India* for October 1913, a preliminary account was given of the results obtained with the acclimatized American cotton known as "Cawnpore-American", and the conclusion was there reached that this cotton met a distinct demand and could be profitably grown, provided the marketing of the unginned cotton (*kapas*) could be organized. It was also shown that there was probably some margin for improvement in the crop itself both as regards uniformity of the lint and ginning percentage. It is now proposed to give a brief account of the results which have been obtained in the improvement of the crop by pure line selection, and of the further information which has been gathered in the course of the attempts made to establish this crop on a commercial scale.

Dealing first with the field crop Cawnpore-American, in its original form, the statement as regards yield previously made has been fully justified, and the results obtained on the Kalianpur Seed Farm show definitely that, on the average, Cawnpore-American is at least as good a yielder as the highest yielding types of *desi* cotton when both are sown with irrigation at the optimum time.

In 1913, careful comparisons on uniform land were made of the yields obtained from Aligarh white-flowered *desi* cotton and Cawnpore-American, both at Cawnpore and Etawah, with the following results :—

	Cawnpore-American	Aligarh white-flowered
Cawnpore . . .	695 lb. <i>kapas</i> per acre .	662 lb. <i>kapas</i> per acre
Etawah . . .	1,187 lb. " " " "	1,139 lb. " " "

A similar comparison was carried out at Etawah, in 1914 and 1915, with the following results :—

	Cawnpore-American	Aligarh white-flowered
1914 . . .	1,066 lb. <i>kapas</i> per acre . .	961 lb. <i>kapas</i> per acre
1915 . . .	699 lb. " " . .	454 lb. " "

The above figures are averages only ; detailed figures are given in the farm reports for the years in question.

With such crops as cotton, however, yields obtained from small experimental plots are occasionally misleading, if for no other reason than because it is possible to give such areas practically perfect cultivation. The results obtained from large fields at the Cawnpore (Kalianpur) Seed Farm, from 1913 to 1917, are, therefore, of interest, and these are given below :—

Yields of kapas in lb. per acre at Kalianpur.

	Cawnpore-American		Aligarh white-flowered <i>desi</i>	
	Area in acres	Yield	Area in acres	Yield
1913	23.0	840	13.0	830
1914	18.9	650	5.6	764
1915	20.5	485	9.8	469
1916	13.8	421	9.5	510
1917	9.15	431	10.4	359
1918	11.0	830	4.0	799

Of these, the only good cotton year was 1913, in which year the average yields of Cawnpore-American and Aligarh white-flowered *desi* were practically identical, but the yields from the best field of American (1,336 lb. per acre) were much higher than those obtained from the *desi* variety (1,053 lb. per acre). The *desi* variety used for comparison is a far higher yielder than the ordinary cotton of the Cawnpore and neighbouring districts, but in respect to quality is the lowest in the province, and its more general introduction would be strongly opposed by most Indian spinners. During the last three years the cotton crop has throughout the province been seriously damaged by excessive

rain, but even so American cotton has yielded on the whole as well as *desi*. As will be seen later, some of the pure lines isolated from the mixed crop are distinctly better yielders than the original crop, and it seems clear that, as regards yield, there is no obstacle to the general introduction of this cotton in the irrigated portion of the Central Circle.

Careful observation of the crop as grown by cultivators, and also detailed observations on our farm crops, bring out certain definite limitations, however, in respect to this cotton, that are of no small importance in its establishment as a commercial crop. It is of primary importance that American cotton should be sown with adequate preliminary irrigation well before the monsoon; failure in this respect results in stunted plants which never recover their vigour. In the early part of the monsoon Cawnpore-American cotton is undoubtedly somewhat more susceptible to water-logging than *desi* cotton; on the other hand, farm results and the experience of cultivators go to show that it is less damaged by heavy rain at the end of the monsoon than *desi* cotton. These differences are undoubtedly due to differences in the root and branching systems, respectively, to which reference will be made later.

It is also clear that, to obtain the best results with cottons of the American type, they must be grown in lines and not sown broadcast—a practice which, though advantageous, is not common with *desi* cotton, even when sown early with irrigation. Further, American cotton responds more readily to good cultivation than *desi* cotton and conversely is apt to suffer more from neglect.

Finally, the necessity of early sowing with irrigation is an important limitation, since there are few villages which in a normal year obtain enough canal water to permit of all their cotton being sown with irrigation. Further, as cotton follows wheat, it may occur that a cultivator will have difficulty in sparing time from his wheat threshing to adequately prepare land for American cotton. The latter point is not, however, of extreme importance, as the optimum time for sowing irrigated *desi* cotton is only some 10-15 days later than that for American, and earlier sowings of *desi* cotton are by no means uncommon.

It is, however, obvious that two essential conditions must be fulfilled if this crop is to be permanently established, *viz.*, (i) an adequate supply of irrigation water, and (ii) adequate arrangements for marketing *kapsas* so as to ensure to the grower the true value of the improved staple which he is producing. The chief practical difficulties in assuring the first requirement lies in the fact that our great canals are organized on a protective rather than on a commercial basis, the object, necessarily perhaps, being to provide a certain amount of irrigation for the maximum

number of villages rather than to provide ideal arrangements for a limited number. The supply from the Ganges is lowest at the end of the cold weather and early hot weather, and the rise in the river (with increased supplies to the canal) consequent on the melting of the snows is sometimes late and leaves little margin before the onset of the monsoon. A minor difficulty arises from the fact that the principal branches and large distributaries, running as they do along main watersheds, do not, in many cases, command the best cotton land which is naturally situated where the drainage is best, *i.e.*, on the fringes of ravines and small rivers and therefore at the tails of distributing channels. Until 1917 there were frequent complaints from cultivators that they did not receive irrigation water in sufficient quantity or for a sufficient time to sow a full area of American cotton. While these were not in all cases well founded, many of the complaints were genuine, and the matter was therefore taken up with the Irrigation Department in order to find a method by which an adequate water supply could be guaranteed.

It was clear that the canal supplies that could be expected during May and early June would not permit of adequate water for American cotton sowings being guaranteed on all canal distributaries, and, the method of selecting villages where supplies would ordinarily be good having proved unsatisfactory, it was decided to concentrate American cotton on a limited number of channels and to ask for a special supply of water for the villages so commanded, followed by a longer closure to enable other channels to obtain adequate supplies for *desi* cotton sowings. This method was tried for the first time in 1917, and, though the increase in area in that year was by no means as marked as was expected, there was a most marked diminution in complaints and a satisfactory increase in the proportion of the crop sown at the proper time. Largely as a result of this, though partly as a result of the excellent prices obtained last year, demand for seed for 1918 sowings has exceeded the supply, and at the time * of writing the whole of the seed available has been distributed, this being sufficient for some 9,000 acres as compared to about 1,600 acres sown in 1917.

The organization of a market for unginned American cotton has been a matter of some difficulty. Whilst it is a comparatively easy matter to obtain a fair market price for any good cotton once it is ginned and baled, the same does not apply to unginned cotton (*kapas*). Throughout the United Provinces no market exists for any *kapas* other than *desi*, and buyers practically ignore staple, some attention being paid to gin-

* It has since been found that this modified system of distributing water for cotton sowings was also advantageous to *desi* cotton on the non-selected channels and led to an increased area.

ning percentage but most weight being attached to colour and cleanliness. Under these circumstances some form of buying agency for American cotton was essential, as otherwise not only would the grower have obtained no premium but the cotton would have been lost to the trade by mixing with *desi*.

In 1912-13 the Elgin Mills Co., Ltd., came forward and guaranteed a premium* of R.1 per maund of *kapas* to the grower, the department organizing the purchase and ginning on their behalf. In 1913-14 and 1914-15, arrangements were made, before the crop was sown, for the same mill to take the cotton after ginning at a price based on Liverpool spot prices for American cotton. In 1915-16 and 1916-17 similar arrangements were made with the Muir Mills Co.

These arrangements were not on the whole satisfactory to either party. In buying even limited quantities of cotton-ahead, spinners naturally hesitated to guarantee a full price, especially as the department could give no guarantee as to the amount of cotton which would be offered. On the other hand, we were not in a position to pay out the full price to the grower until after all accounts had been settled, and the prices obtained in some years were not really satisfactory from the growers' point of view.

In 1917 the sanction of Government was obtained to the department purchasing the whole of the crop of Cawnpore-American cotton and putting the ginned cotton on the open market. This resulted in a premium of Rs. 4 per maund (of *kapas*) being paid to growers, a result which may be considered satisfactory, as, even with the abnormally high prices for *desi* cotton, this amounted to a premium of 25 per cent.

The spinning trials conducted by the Elgin Mills Co., Ltd., in 1912, and the valuation obtained through the courtesy of the British Cotton Growing Association in 1913, established Cawnpore-American as a cotton which was approximately equal to imported American cotton in staple and value. This has been confirmed by subsequent spinning trials and valuations and mill reports. In February, 1918, the cotton of the 1917 crop was sold in Cawnpore at Rs. 635 per *candy* (784 lb.), Bombay quotations on the same date being as follows:—

Fine Broach Spot Rs. 655, equivalent to Rs. 635 at Cawnpore.
Sind-American Spot Rs. 650, equivalent to Rs. 630 at Cawnpore.
Ordinary Broach Spot Rs. 610, equivalent to Rs. 620 at Cawnpore.
Fine Broach March-April Rs. 645, equivalent to Rs. 625 at Cawnpore.

It is clear therefore that in Cawnpore-American we have a cotton of considerable value to the trade and which can be readily sold once ginned and baled. The organization of the market for *kapas* will continue to be

* About 12½ per cent. at rates then current.

of importance until the area is large enough to induce ginners to establish a separate market. For the present year the department is continuing as last year to arrange for the marketing of the cotton.

The period 1914-1918 has been an exceptionally unfavourable one for the introduction of any improved cotton. With a record area under cotton in 1914 a severe slump in prices followed the outbreak of war, which led to a very great reduction of the area under cotton and a general lack of interest by cultivators in cotton cultivation. Our arrangements for the sale of American cotton in 1914 were entirely upset by the closing of the Liverpool cotton exchange, and new arrangements had to be made at the last moment. The premium paid to cultivators (R.1-12-0 per maund of *kapas*) was good if viewed as a percentage on the price of *desi* cotton, but the return to the cultivator was low, and while few growers gave up American, no great development took place in the following year. The 1915, 1916 and 1917 seasons were all unfavourable for cotton-growing on account of excessive rain, and market conditions were also extremely unsettled. In 1916-17 cotton prices showed a marked recovery, but the premium on American cotton was inadequate owing to imperfect marketing arrangements. At present, as already stated, owing to the excellent results of the sale of the 1917 crop and to better irrigation arrangements, much more interest is being shown by cultivators than has been the case since 1911, and a large increase in area has resulted.

II. The Improvement of Cawnpore-American Cotton.

As already stated, a preliminary examination of the Cawnpore American crop showed that a considerable margin existed for improvement in the crop itself as regards ginning percentage, uniformity of lint, and uniformity of agricultural type. The isolation of pure races was therefore started in 1912, and this led to some unexpected results showing that the field crop was far less uniform than first appeared. In selecting plants in the field it was found that there was more variation in habit than would be expected. How far this is due to the effect of hybridization between the original importation (Upland Georgian) and subsequently introduced varieties which had been grown in close proximity to the original on the experimental farm, it is now impossible to say. A number of different types were therefore selected and studied. Avoiding extremes, some 40 plants were chosen in the field in 1912, their characters recorded as far as possible, and selfed seed obtained. The progeny of these plants were individually studied in the following year and characters again recorded. As it was clear that many of the plants originally chosen were hybrids and gave rise to very variable offspring

when selfed, it was necessary to self individual plants in 1914 and again in 1915 before anything approaching to a pure line could be obtained.

The characters to which attention was paid at this stage were (1) branching habit, (2) hairiness of the leaf, (3) colour of the stamens, (4) ginning percentage, (5) length and fineness of the lint, (6) shape and size of boll, and (7), to a less extent, the leaf shape, stem colour and the colour of the foliage. The characters mentioned under (7) were of considerable assistance in the preliminary sorting of the material obtained by growing selfed seed.

The importance of the branching system of the cotton plant, in determining the length of the vegetative period and, therefore, to a large extent, the capability of yielding in the short growing season which obtains in the United Provinces, has been worked out in great detail by Leake¹ in respect to Indian cottons. The relationship of the form of the "plant scaffolding" to yield under defined conditions has also been very clearly pointed out by Balls in respect to the Egyptian cottons (which belong to the American as distinct to the Asiatic group). The literature on the habit of Upland American cottons is voluminous and confused, and it was only after considerable study in the field that the relatively simple relationships existing in the material under examination were cleared up. The various types of plants found in Cawnpore-American ranged in branching habit from the extreme sympodial type with only secondary fruiting branches to a late flowering monopodial type with numerous limbs and producing only a few flowering branches from the main stem at the top. Between these two extremes a complete range of intermediates occur, and, though the branching varies somewhat from plant to plant and is affected by environment (in particular by date of sowing and by water supply), races have been isolated which are remarkably constant in this respect. It should be noted, however, that the appearance of the plant may be very considerably modified by the development of branches from the accessory buds on the main stem. These, on the lower part of the plant at least, are usually non-flowering branches, and in wet seasons in particular such branches develop relatively early and tend to mask the habit of the plant. As such branches rarely throw out tertiary flowering branches early enough to contribute to the yield, and as they interfere to some extent with the setting of earlier flowers, the character, which is shown more in some races than in others, does not appear to be a desirable one. It has been pointed out by Leake² that, in Indian cottons invariably and in extra-Asiatic cottons usually, tertiary

¹ "Studies in Indian Cottons." *Memoirs of the Department of Agriculture in India Botanical Series*, vol. VI, no. 4.

² *Memoirs of the Department of Agriculture in India, Botanical Series*, vol. IV, no. 5.

branches are of opposite character to the secondary branches from which they develop, and that apparent exceptions can be traced to local damage. In Cawnpore-American, however, certain races show a marked exception to this rule and flowering branches are found to arise from flowering branches. This character is inherited regularly and appears in all plants of a race, though in varying degree, and, when well developed, is often associated with the appearance of flowering branches from the accessory buds on the main stem particularly near the top. The character is most common among certain early types that have been isolated. At first sight it would appear to be of great economic importance as it permits of the formation of a larger number of bolls within a limited period. In practice, however, it is very doubtful as to how much it really contributes to the yield of the plant, as the flowers and bolls so formed shed freely and (at Cawnpore) the fruiting branches so formed are rarely of any length or carry more than one boll.

Length of internodes and character of the secondary fruiting branches.

These two characters are closely associated. Plants with long internodes are usually straggling in general habit and tend to produce long weak lateral branches, the lower ones of which are apt to trail on the ground.

Generally speaking, the best type for Cawnpore conditions appears to be a compact plant producing three or four 'limbs' (secondary non-flowering branches) near the base of the main stem and with secondary flowering branches starting early, moderately short internodes and stout branches.

Length of vegetative period prior to flowering.

As pointed out by Leake¹ in connection with Indian cottons, this is closely correlated with the branching habit. The correlation is not quite so obvious in the case of American cotton as in the case of Indian cotton, as the flowering period is more extended and flowering more gradual. The date of opening of the first flower was not found sufficiently definite, being so easily varied by slight damage to the plant, but the date on which flowering from the secondary branches first became general was definite within two or three days, and this together with a record of the branching habit enabled suitable races to be isolated.

¹ *Loc cit.*

Root system.

In the course of this work it was found that some races, one at least of which was fairly satisfactory as regards lint quality, were quite as short in vegetative period as *desi* cotton, and it was hoped that this would allow of later sowings and thus get over one of the practical difficulties referred to on p. 3. This, however, does not appear to be the case. Such very early flowering types suffer severely from boll shedding in the monsoon, as a large part of the crop of bolls is produced before the end of the rains, whilst when sown later these types do not develop well. This unexpected result led to an examination of the root systems of Indian and American cottons, and abundant evidence was obtained that there is considerable difference in this respect. When sown with irrigation early enough for the plants to reach a height of 9" or more before the burst of the monsoon, both classes of cottons developed strong root systems rooting down to at least 4' comparatively rapidly. When sown later but still before the monsoon, both types still succeeded in establishing themselves, though the rooting of the American was less vigorous and the plant less thrifty. When sown in more or less saturated land after the advent of the monsoon, the rooting in both cases was dwarfed, but, while the *desi* cottons still developed fairly healthy roots and were able to establish themselves, the roots of the American were short and poorly developed and the plants stunted.

The method used in examining the roots was to wash each plant out *in situ* with a jet of water, the plant being supported and also lightened by the removal of branches. As work proceeded, the roots as they were freed were supported and a rough note of their position and direction made. It was found, in all plants of appreciable age, that, although the tap-root thinned out comparatively rapidly, it continued to a very considerable depth, following a comparatively tortuous course and being practically unbranched. Little evidence of the second set of secondary roots at the end of the tap-root, such, as is described by Balls for Egyptian cotton, was obtained, but this may have been due to the fact that examination of the root systems of early sown plants was too long delayed, as it is difficult otherwise to understand the great elongation of the tap-root. The extraction of the tap-root complete, from plants of considerable age, was a matter of the greatest difficulty owing to the tortuous course which they follow, and in no case could one be positive that the whole root had been extracted. There is possibly an important field here for further work, which the authors were unable to undertake through pressure of other duties. It is not unlikely that the root systems of cotton sown before and after the beginning of the monsoon

are markedly different, since, temporarily at any rate, subsoil moisture conditions are practically reversed.

The results obtained, as illustrated by the accompanying photographs, at any rate, clearly bring out a qualitative difference between *desi* and American cotton. Photographs 1 and 45 (Plate I) show plants of Cawnpore-American of the same age (80 days), No. 1 having been sown on May 20th and No. 45 on June 15th; the shallower rooting system of the latter is easily recognizable in spite of the fact that No. 1 was very badly extracted and many roots damaged. Photographs 9 and 17 (Plate II) show cotton plants 81 days old, all sown on May 20th, 9 being American cotton (Ca. 10) and 17 *desi* cotton. In all cases the tap-root was broken off in the process of extraction, but it is clear that, when sown at this date, American cotton develops a strong and healthy downward rooting system, though somewhat less quick in developing than *desi* cotton. Numbers 10 [American] and 19 [*desi*] (Plate III) both represent the root systems of cottons 73 days old (sown on May 26th); the American cotton, if anything, has developed the better root system of the two. Photographs 14 and 15 [American] and 24 and 26 [*desi*] (Plates IV and V) represent the root systems of cottons sown on June 3rd, 14 and 24 being 66 days old, and 15 and 26, 78 days old. These roots were much more successfully extracted than those mentioned above, and the much more vigorous development of the root systems of the *desi* cottons is marked though that of the Americans is still not unsatisfactory.

Photographs 6, 13 and 23 (Plate VI) represent the roots of cottons sown on June 15th and 67 days old; 6 is a healthy American plant, 13 a backward plant and 23 a plant of *desi* cotton. Here we appear to be approaching the limit where saturation of the upper soil is interfering with the rooting of the American cottons.

Numbers 40 and 12 [Americans] and 46 and 47 [*desi*] (Plates VII and VIII) represent plants 84 days old (sown on June 15th), 40 being an indifferent plant. The massing of the roots near the surface is at once clear, the vigour of the plant above ground is reflected in its root system, and the more satisfactory development of the *desi* cotton roots is clear.

Photographs 50, 52, 53 and 54 (Plates IX and X) represent the roots of cottons sown on July 7th and 64 days old, 50 being *desi* cotton and the rest American; 52 was the best plant that could be found in the field. The difference is here marked and much in favour of the *desi* cotton. One has only to compare these with the roots of plants of the same age and sown on June 3rd to appreciate the advantage of sufficiently early sowing for both American and *desi* cotton, but where-

as the later-sown *desi* cotton has developed fairly healthy roots the later-sown American failed to do so. Actually the remaining *desi* plants of this sowing matured properly and furnished a crop, though a poor one, whilst the American failed. In one respect the comparison is not a fair one, as in the last two sets, for want of other material, the roots of American cotton plants from newly imported seed were taken for examination. But in view of the gradually increasing difference between *desi* and American cottons throughout the series, this would not appear to invalidate our main conclusions, viz., that the failure of American cotton when sown too late is due to unsatisfactory root development, and that when sown too near the monsoon the American plant develops a shallower root system than *desi* cotton, and will therefore suffer more from temporary surface water-logging (unfortunately not uncommon) and would also suffer more from a period of dry weather and hot sun following wet weather.

A reference to the rainfall graph for 1916 (facing p. 25) will show the character of the season in which these results were obtained.

Light showers which fell in May were of negligible effect, temperatures between times being high and the air dry. Heavy rain ($5\frac{1}{2}$ ") fell on the 9th and 10th of June, followed by a break until the 22nd (but for showers aggregating only 0.1"); on the 22nd a further $5\frac{1}{2}$ " fell and wet weather continued until the 26th, followed by a break until the 6th July from which date rain was continuous until September 3rd with only a slight break in the third week in August. Thus sowings of the 3rd of June were only just up when heavy rain fell, and had barely recovered from this when very heavy rain fell. Sowings of June 15th and later were made under monsoon conditions. The monsoon was fully a fortnight earlier than the average and was unusually strong and continuous.

The middle of the monsoon period in a normal year at Cawnpore is unfavourable to cotton growing owing to over-saturation of the soil, and all cottons receive a definite check during this period. American cotton, if sown sufficiently early, recovers as soon as the rains slacken off and yields well, as does *desi* cotton. Either variety, if sown too late, fails to recover sufficiently to yield well and the American variety cannot be sown so late as *desi*.

Hairiness of the leaf.

Dharwar-American cotton and a number of imported varieties of American cotton have failed to yield at Cawnpore except in unusually dry years, and this result has invariably been associated with an attack of aphid on the varieties which failed. Examination of the leaf showed that the back of the leaf was in all cases either partially or entirely smooth,

and that plants with fully hairy leaves were free from aphid attack even when growing in close proximity with attacked plants. In this respect Cawnpore-American was practically pure, and, though some smooth-leaved races were isolated from it, comparatively few such rogues were found in the field crop. Whether the damage is entirely due to aphid or whether it is partly physiological is doubtful. In smooth-leaved cottons aphid can invariably be found on a cloudy day during the rains, but the wilting of the leaves, which is the first sign of damage to the plant, generally occurs when a period of bright sunshine follows prolonged rain, thus suggesting that excessive transpiration is in part the cause of the plants' loss of vigour. For practical purposes it was sufficient to discard all races the leaves of which were not fully hairy.

Flower colour.

All plants in the field crop of Cawnpore-American, which were examined, showed the creamy petal colour usually associated with Upland American, and no yellow petal flowers could be recognized. In all cases the flower was self-coloured, *i.e.*, no petal spot was present. In Dharwar-American, on the other hand, flowers with yellow petals were not uncommon, and the same was true of some importations grown at the same time, but, as these were all discarded for other reasons, this character was not further considered.

Stamen colour.

An unexpected result was obtained in respect to this character, a number of plants being obtained with golden yellow stamens as distinct from the pale buff usually associated with Upland American. The inheritance of this character is simple as pointed out by Balls; considerable use was made of it in the preliminary sorting, and it has been of considerable use in recognizing natural crosses. Of the pure lines which have been now obtained some show golden stamens, others pale buff, and they were easily obtained pure in regard to this character.

Ginning percentage.

As has been shown by Leake this is not a single character, but, on the other hand, the improvement of the proportion of lint to seed is an important matter since the field crop of Cawnpore-American gins from 2 to 3 per cent. below *desi* cotton, thus reducing the premium which can be paid to the grower for his *kapas*. The accurate determination of ginning percentage on small samples is no easy matter and variations are considerable, but it was possible to locate and discard certain races

which showed a low ginning percentage, and to retain others which were not only satisfactory in other characters but possessed a high average ginning percentage. It was considered that yield and lint quality were the first essentials, and by re-selection of the higher ginning individuals, from races satisfactory in other respects, it has been possible to obtain on a field scale a number of types which gin considerably higher than the original field crop. The method is admittedly inexact, but in the same way Clouston in the Central Provinces and Parr in the United Provinces were able to isolate types of *desi* cotton which show markedly higher ginning percentages than the unselected field crop. In the preliminary examination of small samples it was also found that an examination of the way in which the seed was covered enables the more constant ginning families to be recognized. The ginning percentage of cotton when grown as a field crop varies somewhat from year to year, being affected by the season, and it is the general experience of ginning factories, as also on our experimental farms, that in certain years the average is high and in others low. For this reason considerable importance is attached to the trials of the various types on a field scale which are referred to later—the more so as it has been our constant experience that the ginning percentage obtained when a cotton is grown fairly closely on a field scale is higher than is obtained from a limited number of plants grown at wider intervals to permit of individual study.

Lint quality.

A constant fault of the field crop of Cawnpore-American is the variation in the staple. The detailed examination of the lint from a number of plants showed conclusively that this was largely due to the presence of races with short and rough fibre, and several of these have been isolated pure, though subsequently discarded. Plants were found with lint as short as 0.7", and the importance of the removal of these from a crop which was commercially graded as staple 1½" (British Cotton Growing Association 1913) is obvious. Fortunately it was easy to recognize at least one of these families by its vegetative characters, and consequently we have been able to rogue it out on our seed farm and it is now rarely found in the field crop. Another source of unsatisfactory lint quality, particularly in certain years, was the presence of certain late flowering types which did not mature their lint well. Such types have been discarded for this reason as well as on account of their low yield per acre, though as regards actual length of lint they have been by no means unsatisfactory. Having obtained races of uniform agricultural habit and pure in respect to more obvious characters, as many individuals as possible were grown from selfed seed and the lint of each

examined. Families showing extreme variation were discarded at once except in a few cases where unusually good lints occurred, but even these mainly resulted in disappointment. From those that showed fairly uniform and satisfactory lint, re-selections were made, and finally families which were reasonably uniform in lint characters were obtained. Length was easily determinable on the combed seed and was checked by measurement on the ginned cotton. Fineness was not so easy to determine on small samples, and it was necessary to carry on a large number of selections only to discard them later. Strength presented the greatest difficulty of all, and it was necessary to wait until sufficiently large samples were available for commercial examination before any decision could be arrived at. Generally speaking, however, it was found that samples obtained from races that ripened well were satisfactory in this respect.

The senior author is greatly indebted to several Cawnpore spinners, particularly to Mr. Vernon, of the Elgin Mills, and to Mr. Holden, then of the Muir Mills, for assistance in judging small samples, and to Messrs. Tata and Sons, of Bombay, who (at the request of the Imperial Cotton Specialist) examined a number of the selected types which were being tried on a small plot scale and whose valuations and criticisms have been of the greatest help.

Shape and size of boll.

This character has been of use in sorting out the various families, and the relation to yield is also obvious. Considerable variation was obtained in the field crop from small round bolls barely $\frac{3}{4}$ " in diameter to large pointed bolls comparable with those produced by some of the modern "Big Boll" American varieties. The races finally retained include both medium and large boll varieties, but it was found that the opening of the boll was of more importance than the size. In some races the boll opened badly, picking was difficult and the lint ripened badly; such were discarded. No attempt was made to select for five-locked bolls though these were by no means uncommon.

Method of work.

The work published by Leake, Balls and others having clearly shown that any attempt to improve cotton by ordinary selection was at best a most uncertain affair, it was decided that only by the isolation of pure lines could definite results be hoped for, and that this must necessarily involve protection from natural crossing if results were not to be entirely vitiated. This was amply confirmed in the course of the work. On a

few occasions it was necessary to sow seed produced by unprotected plants and results were in all cases unsatisfactory. As long as single plants were being dealt with these were protected by coarse mosquito nets during the principal portion of the flowering period; bolls that set under the net were marked and only seed from these was taken for sowing in the next season. It was not possible to keep the plants under the net throughout the whole of the flowering period; partly on account of the tendency of the plants to grow too tall and because the presence of the net interfered with the ripening of the bolls, and partly because it was impossible to net more than a limited number of plants daily. In the early stages, therefore, in order to obtain more *kapas* from each plant for examination of lint and ginning percentage, bolls from unselled flowers were separately marked and collected.

Once a family appeared pure, a number of plants were covered with a large net so that at most they could only cross-fertilize each other, and, owing to the absence of bees, the large majority were probably self-fertilized. In this way a pure stock of seed was obtained for further multiplication on a field scale and a stock maintained from year to year.

In 1912 some 40 plants were examined in the field and netted, and selfed seed of 32 was sown in 1913 and all the progeny examined. A number were discarded by field examination in 1913, and a further series of rejections made after examination of the lints and ginning percentages. Selfed seed from 85 individuals was carried on into 1914, and in that year a few families appeared pure and a certain number of these were protected by large nets containing 20 plants (*kapas* being collected and examined singly), while other individuals were placed under single nets since it was not possible to examine the lints until it was too late to protect flowers.

In this year it was possible to reject a very large mass of the material for various reasons and 29 families were carried on under permanent numbers. Many of these were subsequently discarded, and in the case of others re-selection of individuals for lint and ginning percentage was necessary.

The most promising families were not, however, obtained pure until 1915.

The net result of this work has been to isolate from the field crop of Cawnpore-American a number of pure lines. These can be grouped under a few types as regards their agricultural characters.

Description of the various races isolated.

As stated above, rejections were freely made as work progressed, and in 1916 only 14 selections were grown out of the 29 originally brought

under permanent numbers. The remainder were rejected for various reasons, chiefly on account of unsatisfactory habit or indifferent lint. Those retained fall into four groups.

I. *Very early* : *Ca 10, 11 and 28*. These are all characterized by extremely small development of the limbs (secondary vegetative branches) ; they are in heavy flower within 54 days of sowing, depend for their yield almost entirely on the secondary fruiting branches, and are the nearest approach in habit to the local *desi* cotton that occurs amongst the Americans. Numbers 10 and 11 have characteristic red stems. The internodes are comparatively short : 10 and 11 produce small bolls, those of 28 being somewhat larger. Numbers 10 and 11 possess the fully hairy leaf ; No. 28 has now been discarded as it is not fully rough-leaved and under unfavourable conditions does badly though good enough with really good cultivation ; an attempt to obtain by re-selection from this a race with fully hairy leaf failed.

II. *Early* : *Ca 5*. This type is distinct from those described above. The plant is low and bushy ; good limbs to the number of three or four are readily developed ; and the plant is extremely prolific and shows the useful quality of setting bolls well under comparatively unfavourable conditions. The yield is largely dependent on the secondary fruiting branches, but the tertiary fruiting branches also contribute considerably. The boll is large and pointed. This race possesses flowers with golden yellow anthers and is pure in respect to this character. In respect to the development of the first flowers it is but little later than the first group, flowering commencing 54-57 days from sowing and the plant being in full flower in about 64-69 days. The secondary fruiting branches are stout and the internodes medium short.

III. *Ca 7 and Ca 9*. This pair and several others which were discarded for lint faults form a group with a slightly longer vegetative period than *Ca 5*, being about a week later in flowering when sown at the same time. In general habit they are somewhat larger than *Ca 5*, taller and with longer internodes. The boll is pointed. Flowering is more gradual and the development of tertiary fruiting branches early enough to add materially to the late yield. When sown early, vegetative branches frequently develop from the accessory buds ; and on good land in a wet season this type grows large and bushy but is still well within the necessary limits.

IV. *Medium late group* : *Ca 1, 3, 23 and 26*. These form a distinctly later group, flowering about 70 days after sowing though the earliest flowers in small numbers appear earlier. Though the number of limbs rarely exceeds four or five and the first secondary branch appears low on the main stem the plants of this group, of which 1 is the most typical.

develop large strong limbs, and the result in a wet season is the partial suppression of the earlier fruiting branches. In some years these families have yielded well and Ca 1 is perhaps the most typical of the original field crop. But as a considerable portion of the crop is dependent on the tertiary flowering branches, late sowing or an unfavourable season might result in a very poor yield—a matter which is being tested further.

Ca 23 differs from the others in habit, though similar in flowering time, and is a small compact plant with short branches and a small boll. Being apparently very hardy and possessing the fully hairy leaf in a marked degree, it was retained for a number of years but has now been discarded. The others are biggish, bushy plants with fairly large bolls, medium long internodes, and stout branches growing to a considerable height.

Theoretically these should be the best yielding group of the lot as they come into heavy flower just as the monsoon slackens off when sown at the proper time; in practice they seem to be a trifle on the later side.

V. *Late: Ca 15, 1 and 18.* There is a little doubt about the position of 15, 1 in this grouping as it is a re-selection and in 1917 was only very slightly later than the preceding group. Ca 18 is undoubtedly a later type, flowering only occurring after 78 days from sowing.

Ca 18 is just on the limit for successful growing at Cawnpore. When sown at the usual time on good land it grows very tall and develops strong limbs with a good development of fruiting secondary branches though these are comparatively late. The tertiary flowering branches do not develop in time for the bolls to open well except in dry years.

Group V is only late in a relative sense, many far later forms were found in the process of selection from the field crop and, as they matured bolls satisfactorily in the very dry year 1913, were carried on until 1915, after which they were discarded, it being clear that they could never yield well under average conditions.

Field tests.

The next stage in the work was naturally the testing of these races for yield and commercial suitability, and the retention and multiplication of those which would appear to be the most profitable to the grower. It has been assumed from the start that it is not worth while growing American cotton at all unless a certain standard of quality can be maintained, and all really inferior types have been discarded without further trial. The same applies in a limited degree to ginning percentage, and no type was retained for multiplication with a ginning percentage inferior to the existing field crop. Subject to these limits, however, the

principal consideration is yield. Market fluctuations in India were great even under pre-war conditions, and there is a marked want of parity between the prices of cottons of different styles. Generally speaking, short staple cottons frequently command prices out of proportion to their intrinsic value. This being the case, it is clear that to depend on the extra price obtained for quality to make up for any considerable difference in yield would be most unwise. Staple and ginning percentage from the growers' point of view are both commercial qualities, both affecting the value of his *kaps*, and deficiency in the one may be made up by extra value received for the other.

The testing of the various pure lines obtained has been considerably handicapped and delayed by a series of unfavourable cotton seasons. The season 1915 was favourable to cotton until the end of August when unprecedented storms occurred, which nearly ruined the cotton crop by actual flooding and by the destruction of flowers and bolls. In 1916 an exceedingly wet year was experienced. No phenomenal falls of rain occurred but the rainfall from June to October aggregated 43", or roughly 50 per cent. above normal, and there were practically no breaks of any length. As might be expected all varieties of cotton did badly.

In 1917 the weather until the middle of July was normal and favourable to cotton growing. The next month was unusually wet as was also the second half of September. Monsoon rainfall aggregated 38", which was some 30 per cent. above normal, and the cotton crop was on the whole poor.

Under these conditions, with yields only some half of the normal, one can only accept the results of comparisons of yield with considerable reserve. The same applies to valuations of the cotton as under more normal conditions results might be different.

Yields in lb. per acre seed-cotton (kaps), Cawnpore.

No.	1915	1916	1917 I	1917 II	1917 III	1918
Ca 1 . .	685	507 : 477	496	383	...	542 : 521
" 3 . .	...	(2) 491 : 605	585	614	451	...
" 5 . .	582	599 (1)	606	733	426	967
" 7 . .	...	498	522	505	384	1,110
" 9 . .	...	461	583	(127) 491	423	927
" 10 . .	552	410	573	...	...	...
" 11 . .	537	507	626	637	...	765 : 802
" 15 (15, 1) . .	...	...	363	...	...	993
" 18 . .	619	383 : 474	481	...	...	776
" 23 . .	550	527	564	...	...	...
" 26 . .	...	344	436	437	342	...
" 28 . .	520	445	507	...	...	...

Kalianpur—Sowings at different dates.

No.	1916			1917					
	I	II	III	I	II		III		
	DATE OF SOWING								
	19th May	28th May	15th June	22nd May	29th May			9th June	
Ca 1	423	354	253	498	415	335	305	226	270
" 5	521	638	302	600	516	417	496	309	376
" 11	613	531	355	542	544	374	439	323	340
" 18	395	...	313	415	439	387	358	121	245
" 23	583	...	452	481	550	439	...	301	413
" 28	518	484	151	424	391	327	278	160	265

In 1917, seed being available, the following numbers were grown on a field scale and gave the following yields :—

No.	Kopas per acre
	lb.
Ca 5	61
" 11	551
" 1	413
" 18	371
Ordinary Cawnpore American	416, 419, 457

In considering the yields for sowings at different dates, the dates on which the monsoon commenced in the two years concerned, viz., June 9th and June 16th respectively, must be allowed for, both these being earlier than the normal and this being distinctly to the disadvantage of the late sown crops. In each year the rainfall in June and July was above the average.

The following table shows the ginning percentage and the length of staple as determined at the experimental farm for the years 1915-1917 :—

Ginning percentage and length of staple determined at the Kaliaipur farm for the years 1915-1917.

Groups.	Ca	GINNING PERCENTAGE			STAPLE LENGTH			ABSTRACT OF TATA & SONS' VALUATION			
		1915	1916	1917	1915	1916	1917	1915		1916	
								Count (Warp)	Class	Count (Warp)	Class
I	10 11 28	31.9-32.2 33.3-33.9 31.4-32.2	32.0 32.5 31.8	31.9 32.5 32.0	0.95 1.05 0.90	0.95 1-1.05 1.05	0.9-0.95 1.0 0.90	16 16 24	IV IV II	10 16-20 12-14	IV II III
II	5	35.5	34.5	34.0	0.95 C	0.95	0.95	16	IV	12-14	III
III	7 9	...	33.1 33.4	33.3 33.2	1.15 1.15	1.05-1.10 F 1.05-1.10 F	1.05 F 1.10 F	...	...	24 24	I I
IV	3 23 24 26	33.0-33.3 33.1 31.9-32.0 31.4	35.3 32.3 32.0 32.7	34.0 32.3 31.9 32.5	1.05 1.00 1.05	0.90 C 1.05 1.00 R 1.05-1.10	C.90 R 1.05 1.00 1.00	...	...	12-14 10 12-14 20	III IV III II
V	15, 1 18	...	32.34 Var.	34.7 32.34	1.10 1.15 F	1.10 1.15	1.05 1.10	...	...	20 10	IV IV
								20	III	10	I

F = Fine, R = Rough, C = Coarse.

We are indebted to the courtesy of Messrs. Tata Sons & Co., Bombay, for the following commercial valuation and detailed reports on the various cottons.

1915 crop.

Price basis.—All prices in rupees per candy of 784 lb.

Ordinary Sind-American .	310	Kumpta	345
Good Sind-American .	325	Navsari	375
Saw-ginned Dharwar (American) .			320
Madras Cambodia			365
Ordinary Cambodia			334
Ca 2 will spin 30's warps			340
„ 28 „ 24's „			330
„ 1 } „ 20's „			325
„ 17 {			
„ 18 {			
„ 23 {			
„ 10 }			
„ 11 } „ 16's „			310
„ 5 }			

1916 crop.

Price basis.—

Saw-ginned Dharwar .	390	Fine Surat	425
Fine Broach	390	Navsari	450
Group I—			
Ca 9 } good for 24's warps strong and uniform; Ca 9 a little			
„ 7 } superior in length			410
Group II—			
(a) 26 } will spin 20's warps			395
15, 1 }			
(b) 14 } „ 16-20's „			385
11 }			

All tolerably long in staple but fibre weak and not uniform Ca 11 and 14 being very irregular.

Group III—			
Ca 3 }			
„ 2 } will spin 12's—14's warps			370
„ 1 }			
„ 5 } All short but uniform			360
„ 28 }			
Group IV—			
Ca 18 } Good for spinning 10's warps, 18 the best and fairly			
„ 23 } uniform, the rest variable: all weak			340
„ 10 }			

1917 crop.

Price Basis.—

Navsari	785		
Sind-American	720	Surat	753
Saw-ginned Dharwar .	700	Fine Broach	725
Group I—			
Ca 9 } Good for 40's warps, almost equal to Navsari			785
„ 18 }			

Group II—		
Ca 7	} Good for 30's warps, may be compared with Surat	755
" 11		
" 15, 1		
" 23		
" 28		
Group III—		
Ca 1	} Good for 20's warps, equal to Fine Broach	720
" 26		
Group IV—		
Ca 3	} Good for 16's warps	700
" 5		

All the samples are good in strength except 15,1 which is a little weak and fine soft and silky.

NOTE—

1915 and 1916	. Samples were hand-ginned.
1917	. Samples (except 15,1) were from fair-sized plots and were all machine-ginned (Platt's roller gin).

In considering these results one is at once struck by the effect of season, the effects of the phenomenally wet season of 1916 being to reduce the quality in all cases and to produce weak cotton on the whole.

Ca 9 stands out as the best throughout in respect of lint quality, is satisfactory, though not the best, in point of ginning percentage, and is also a good yielder. Ca 5 is the most consistent yielder and has the highest ginning percentage but is in the lowest class as regards quality. Ca 7 is but little inferior to Ca 9.

Certain of these selections have behaved very irregularly as regards lint quality. Thus Ca 18 was very fair in 1915, bad in 1916, and equal to the best in 1917. This variation appears to be closely related to its late ripening habit.

Ca 11 has done better in 1916 and 1917 than in 1915 but requires further trial. Ca 28 has also been variable but has been discarded for other reasons as also 23.

Through the courtesy of Mr. F. Hodgkinson, of the Indian Cotton Committee, the following valuations of samples from the 1917 crop, by the expert brokers to the British Cotton Growing Association, have been obtained :—

" Ca 1 23d.	. Good colour, about good middling in grade, staple 1" to 1 $\frac{1}{8}$ " rather mixed.
" 3 21d.	. Good colour, good middling in grade, rather rough, staple $\frac{3}{4}$ " to $\frac{7}{8}$ ".
" 5 21-50d.	. Rather dull, barely good middling, $\frac{7}{8}$ " to 1" staple.
" 7 24-50d.	. Good middling, strong and silky, staple 1 $\frac{1}{4}$ ".
" 9 24-50d.	. " " " 1 $\frac{1}{4}$ ".
" 11 21-50d.	. " " " good colour, 1" to 1 $\frac{1}{8}$ " staple.
" 18 24-50d.	. " " " good colour, 1 $\frac{1}{4}$ " staple.
" 26 23-00d.	. " " " good colour, 1 $\frac{1}{8}$ " staple.
" 28 21-00d.	. " " " good colour, staple $\frac{3}{4}$ " to $\frac{7}{8}$ ".

" All based on July American futures 22-00d. per lb., good middling American 21-56d. per lb.

" The Ca 7, 9, 18 are very good and are cottons which could be used extensively in Lancashire, and if India could produce any quantity there should be an excellent demand. Of course you will understand that prices are abnormal and that it would not always be possible to obtain a basis of 250 points *on* for such cotton. Probably 70 to 100 points *on* would be nearer the mark. No. Ca 26 is also a fair cotton and could be used, but not to the same extent as the others.

" These samples are of course a great improvement on the samples of Punjab-American 1R."

From the above report it is clear that most of these cottons would fetch prices equal to American in Lancashire, and that three of them are in every way suitable for Lancashire requirements. In the British Cotton Growing Association report of 1913, the unselected Cawnpore-American was graded as low middling American with a staple of $1\frac{1}{8}$ ", silky, strong but irregular. In Ca 7, 9, 18 the length of lint has been maintained without the irregularity which was undoubtedly due to a mixture of races.

The field testing of these groups is still in progress, a series of test plots having been sown at different dates over a period of a month or so. Results up to the present would indicate that the families 5, 7, 9 are the most likely to be really good yielders under average conditions. Earlier types flower too freely before the end of the rains and in most years lose a lot of bolls by shedding, later types do not mature a sufficient proportion of the bolls formed on the tertiary fruiting branches, on which they are largely dependent for their yield, before the cold weather.

It is at any rate of interest to note that a set of selections of considerable value have been obtained and that the best of them are suitable for spinning much higher counts than was considered feasible¹ with the unselected field crop. The apparent suitability of these cottons for relatively fine warps is of particular importance.

III. Trials of New Importations.

Concurrently with the attempts, which have been described above, to improve Cawnpore-American cotton by the selection of pure lines, a number of recent importations have been tried. In 1912, the following varieties obtained through the kindness of Mr. Henderson (then Deputy Director of Agriculture, Sind) were grown :—

Toole, Texas Big Boll, Black Rattler, Boyd's Prolific, Allen's Long

¹ Reports of Elgin Mills spinning trials. *The Agricultural Journal of India*, vol. VIII, pt. IV, 1913.

Staple and Peterkin. To these were subsequently added Griffin and Triumph.

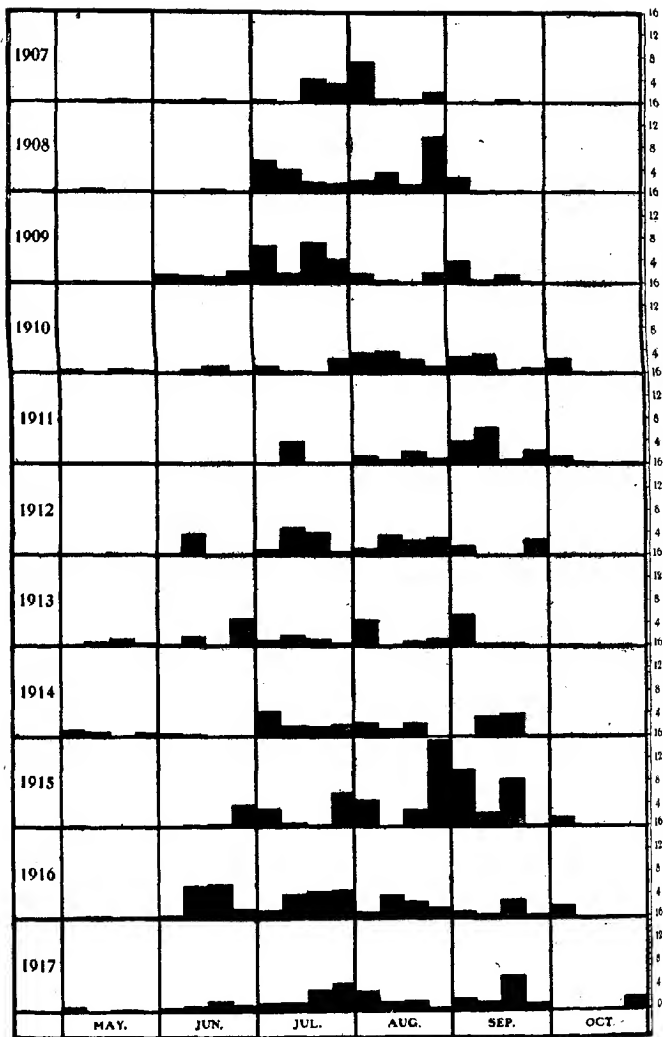
A number of "acclimatized" American cottons were also tried, *viz.*, Dharwar-American, Buri, and some Lyallpur-American selections kindly supplied by Mr. Milne. None of these cottons did well in 1912 which was a fairly favourable season, and Cawnpore-American stood out as the best. In 1913 with a very dry season many of the imported Americans yielded extremely well. Simultaneously with the field trials of these imported cottons, an attempt was made to isolate from them the races best suited to our conditions, since they were none of them homogeneous, and it was thought that this method might lead to more definite results. In particular an attempt was made to isolate rough leaf types. These efforts only resulted in disappointment. In 1913 all cottons grew well and it appeared that stapled varieties like Black Rattler could be successfully grown, and types of plant which in general habit differed little from Cawnpore-American were picked out. But in the subsequent wet seasons these all went down with aphids and the usual "red leaf" damage that follows.

In 1914 a further importation of modern American varieties was made and the following varieties were tried:—Columbia, Foster, Durango, Trice. All these were excellent for our conditions in branching habit and date of flowering, but all went down with aphids and all possessed a smooth leaf. In this year two selections from Black Rattler and Boyd's Prolific showed promise but failed later.

In 1917 some more new importations from America were tried, *viz.*, Cleveland Big Boll, Cook, Simplin's Ideal, Perry, King and Myatt's Early Prolific. These failed in the same way as earlier importations and were dropped.

Dharwar-American. As a field crop this had proved inferior to Cawnpore-American in 1911, but some selections were made from it and carried on for a number of years, since Dharwar-American is an old established crop in Bombay and is believed to have been originally New Orleans while Cawnpore-American is believed to have been Upland Georgian. The field crop was unsatisfactory on account of the large number of smooth-leaved plants, but it was possible to find rough-leaf types. These were discarded later, being inferior to those obtained from Cawnpore-American in other characters.

Buri. Seed of this cotton, the origin of which is not very definitely known but which may have been imported at the same time as the lots from which Cawnpore-American and Dharwar-American originated, was obtained from Aligarh where in dry years it had been showing some promise. At Cawnpore, except in 1913, it was unsatisfactory on account



Block by Government School of Arts and Crafts, Lucknow.

Chart showing monsoon rainfall at Cawnpore.

of its long vegetative period and late flowering, the plant growing large and bushy but producing little cotton. Nor was it possible to isolate an earlier race from it. The fault appeared to lie in the general habit of the plant, since even when sown early it did not cease vegetative growth and develop flowers early enough to yield well before the cold weather set in. This cotton clearly requires either drier conditions than exist at Cawnpore in an average year or else a later cold weather resulting in a more lengthy fruiting period.

Lyallpur-Americans. These appeared to be too long in vegetative period and too bushy in habit for our conditions and were dropped after the second year's trial. This was not unexpected as American cotton occupies a different place in the rotation in the Punjab canal colonies to what it does in the United Provinces, and it was hardly likely that a cotton selected to suit those conditions would also do well at Cawnpore.

These results, though negative, are of importance as showing the danger of wholesale importations of exotics. Whether their failure is entirely due to their lack of the hairy leaf is uncertain, but it is significant that most of the types tried were satisfactory in all other readily recognizable characteristics.

IV. Variations in Climatic Conditions from Season to Season.

As pointed out by Leake and Parr¹, the cotton-growing season in the United Provinces is characterized by its relative shortness, and this is aggravated by the nature of the rainfall during the middle period during which rain is so heavy that the soil is more or less constantly waterlogged and a definite check to the growth of the plant occurs. A reference to the table for weekly rainfall (Appendix II) and to the graphs for same (*see opposite*) will show that in the past ten years there has been very considerable variation in the course of the monsoon. Thus the first rainfall has been received any time between the first week in June and the middle of July, and there have been equally considerable variations in the subsequent course of the monsoon. It is generally recognized that for irrigated cottons near Cawnpore the less the rainfall the better the crop, and for cottons sown with the rains the same is roughly true, provided there is enough moisture at a sufficiently early date to permit of sowings, and that the crop receives enough rainfall during the early part of the monsoon to establish itself. Thus the two best recent years as regards cotton yields have been 1908 and 1913 when the irrigated crop was exceptionally fine and yields as high as 500 lb.

¹ *The Agricultural Journal of India*, vol. VI, p. 1.

per acre of *ginned* cotton were obtained. Such seasons are, however, the exception and are only mentioned because in such years almost any cotton will yield well, and the results obtained may consequently be very misleading since under these conditions not only are yields unduly favourable but the habit of the plant is appreciably modified and late types do unusually well since they receive no check in growth.

Generally speaking, our monsoon can be divided into three periods, so far as cotton is concerned, and damage in one or the other by excessive rain must be expected, whilst in some years, such as 1916, rain may be excessive throughout, continuous wet weather being more disadvantageous to cotton than heavy falls with marked breaks.

The year 1915 is an example of a season favourable as regards the initial period and unfavourable at the end but presenting no unusual features in the middle period. With light rain up to the middle of July all types of cotton made a good start. The second period with considerable though not very excessive rainfall encouraged considerable vegetative growth. But the third period was disastrous and the heavy storms and generally wet weather then experienced resulted in the loss of nearly two-thirds of the crop. Not only were flowers destroyed and bolls prevented from setting, but the waterlogging was so severe as to cause the shedding of early bolls which were already well developed, and the plants were generally weakened.

The converse effect is perhaps best seen in 1912 when rainfall was considerable in the early stages and late sown crops were only established with difficulty, but the rainfall in September was light and the crop was on the whole good though there was a tendency to excessive vegetative growth.

The above considerations, coupled with the fact that cultivators' land is as a rule inadequately drained—being unfortunately often incapable of any radical improvement in this respect with our present system of holdings—make it clear that resistance to waterlogging is a primary essential for any cotton that is to be established in this part of the United Provinces. There seems no method of testing this other than by careful field trials of pure lines coupled with detailed observation over a series of years. It is for this reason that so many types have been retained and that their testing is not yet completed.

V. Cultivation Experiments.

From 1912 onwards a series of experiments on the cultivation of American and *desi* cottons were carried out at the Kalianpur farm, Cawnpore. It is only proposed to give the general conclusions arrived

at here: for details the reader is referred to the annual reports of the experiment station.

1. Early cultivation.

In the United Provinces cotton commonly follows wheat and very little cultivation is given prior to sowing, the usual practice being to plough for the first time when the land is flooded before sowing. A series of careful experiments showed that much better results were obtained if the land was flooded and ploughed immediately after the wheat harvest, and left as a broken fallow until sowing time instead of being allowed to bake hard until just before sowing. Also although this involved two floodings instead of one, there was an advantage even from the irrigation point of view in early ploughing, since sowing time is the period of greatest pressure on the canal supplies and a broken fallow was found to require less water than an unbroken fallow. Early ploughing was equally advantageous for *desi* cotton. This result is what one would anticipate, but the practice of early ploughing is difficult to introduce as both men and cattle are then fully engaged in threshing operations.

2. Line versus broadcast sowing.

Desi cotton in these provinces is usually sown broadcast though sowing in line is undoubtedly better— at least for irrigated cotton. In the case of American cotton sowing in lines is almost essential if the best results are to be obtained, as otherwise thinning and weeding are badly carried out and a large number of plants are badly developed in consequence.

With really good cultivation and careful sowing a distance of 3' × 3' is hardly too much from plant to plant, but on the whole a distance of 3' × 2' in really good fields and 2' 6" × 1' 6" in average fields has proved most satisfactory. With wider plantings there is the risk of loss of yield through imperfect germination (to which cotton is particularly liable) or through poor development in an unfavourable season.

3. Ridge versus flat sowing.

When cotton is sown in lines in the United Provinces the country plough is generally employed, the seed being dropped by hand in the shallow furrow so formed. Ridge sowing on the Egyptian system was tried for two years and at first showed some prospects of success, but generally the germination was not so satisfactory as by the commoner method; no proportionate advantage to the plant was recognizable and the additional cost of labour was considerable.

APPENDIX I.

Note on 1918 results.

While this bulletin was in the press some results from the 1918 crop have become available, and certain of these have been incorporated in the text. The year 1918, though extremely abnormal, was more favourable to irrigated cotton than either of the three preceding years. As will be seen from the subjoined table, rainfall was extremely low, the season being the driest for some 40 years. Results obtained in such a season have naturally to be accepted with some caution as the crop was entirely raised on irrigation and yields were largely determined by success in timing the waterings—a point on which we have no previous experience at Cawnpore to guide us.

At the Kalianpur farm Ca 9 was the most consistent yielder on a large scale: the results from plots sown at different times were as follows:—

Yields of unginned cotton (kapas) in lb. per acre.

	First sowing May 14th	Second sowing May 24th	Third sowing June 16th
Ca 1	682 488	556 498	616 637
Ca 5	587 742	575 763	707 853
Ca 7	582 587	661 755	661 725
Ca 9	494 602	602 694	668 746
Ca 11	461 513	621 658	685 701
Ca 13,1	585 740	595 703	633 845

At the Experimental Farm, Ca 5, 7, 9 and 11 have all yielded well.

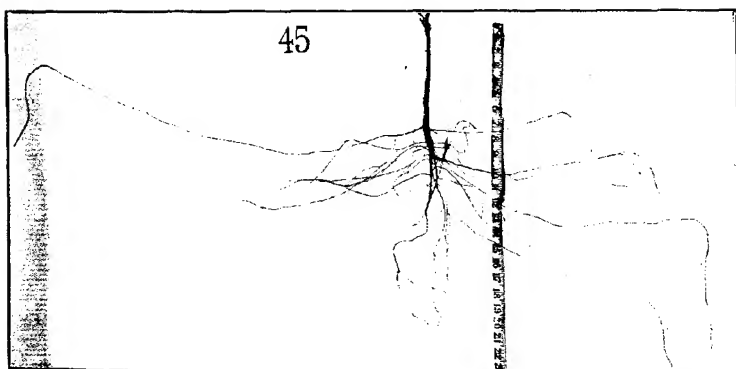
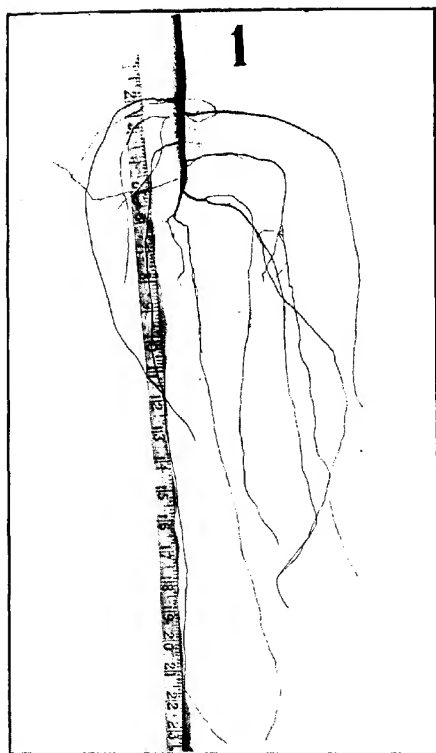
Rainfall during 1918, in inches.

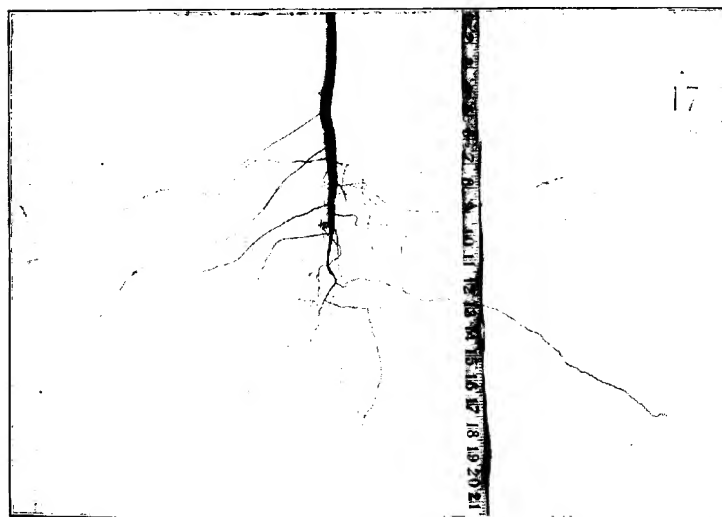
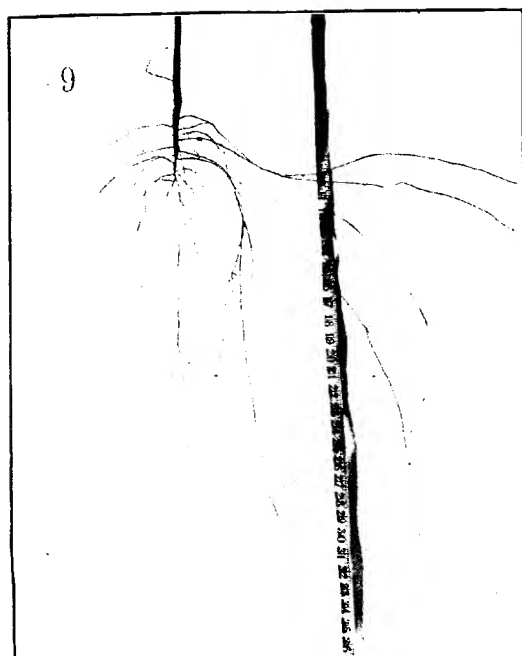
May—	
1st to 7th	0.28
8th to 15th	nil
16th to 23rd	nil
24th to 31st	nil
June—	
1st to 7th	0.65
8th to 15th	0.17
16th to 23rd	nil
24th to 30th	0.91

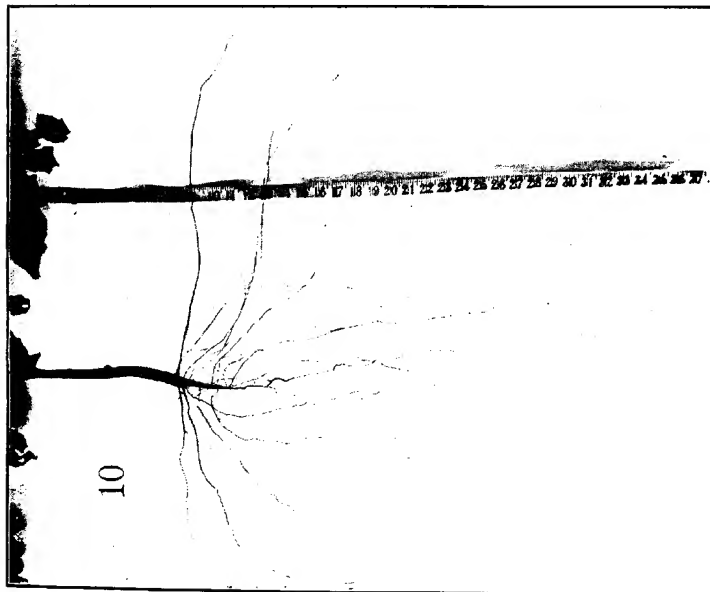
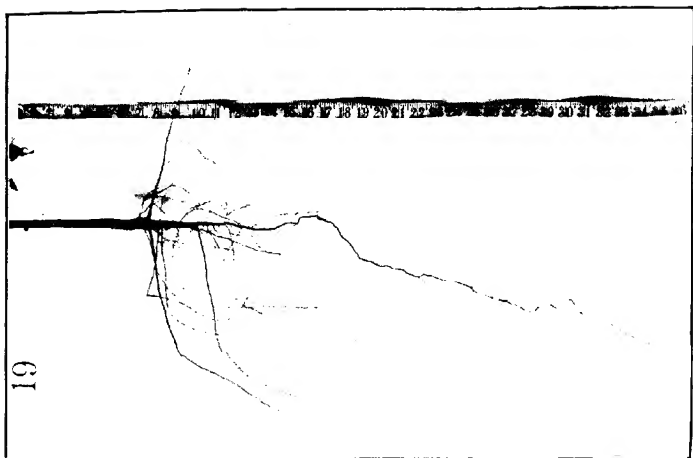
CAWNPORE-AMERICAN COTTON

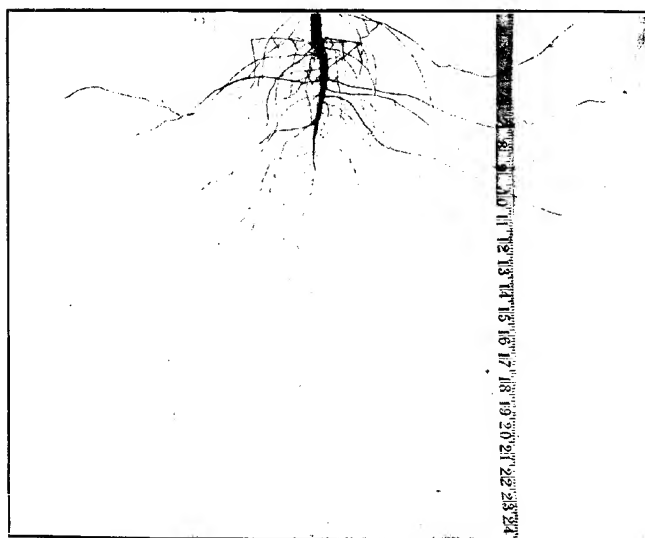
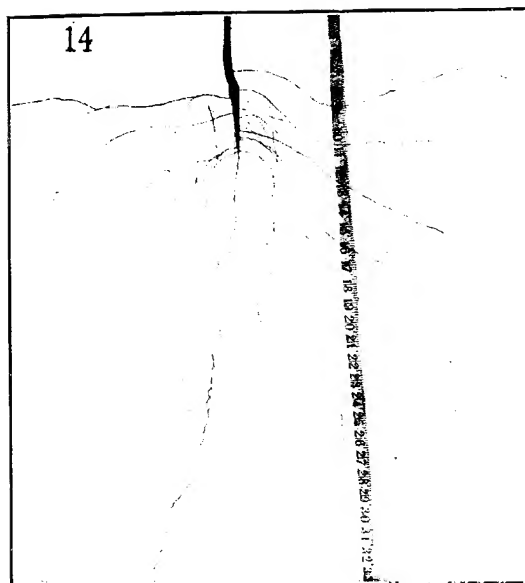
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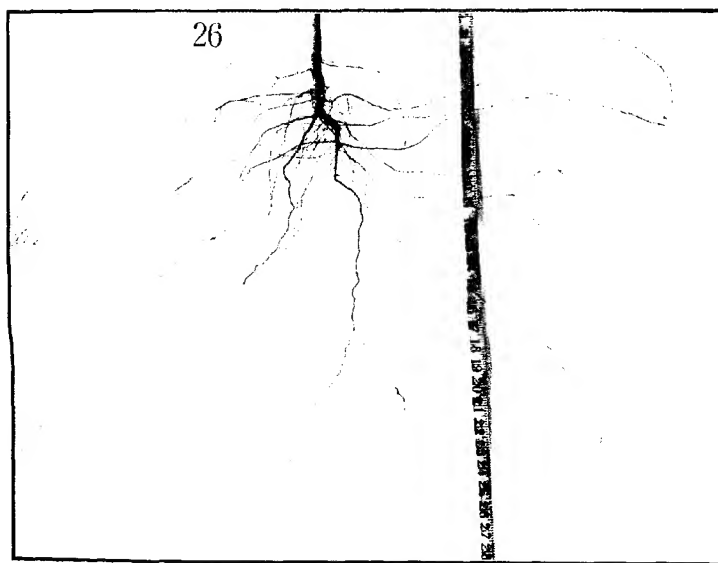
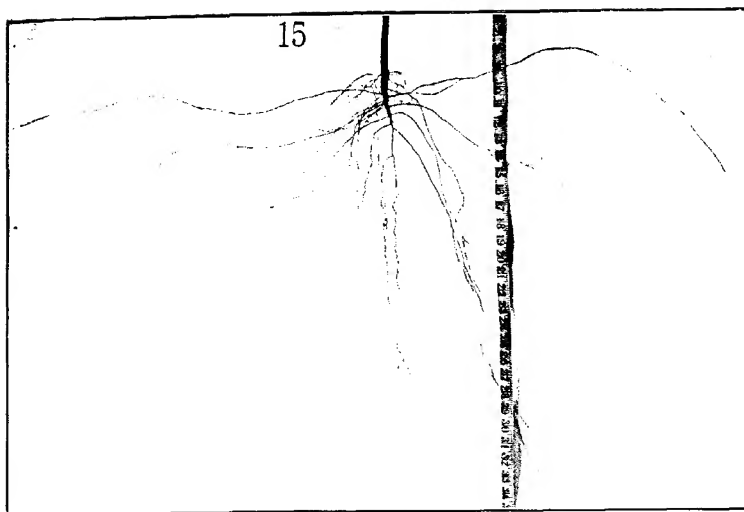
July—									
1st to 7th	0-25
8th to 15th	0-78
16th to 23rd	0-19
24th to 31st	0-24
August—									
1st to 7th	0-01
8th to 15th	.	.	.	.	.	.	.	.	nil
16th to 23rd	.	.	.	.	.	.	.	.	3-13
24th to 31st	.	.	.	.	.	.	.	.	2-17
September—									
1st to 7th	.	.	.	.	.	.	.	.	1-28
8th to 15th	.	.	.	.	.	.	.	.	nil
16th to 23rd	.	.	.	.	.	.	.	.	nil
24th to 30th	.	.	.	.	.	.	.	.	nil
October	.	.	.	.	.	.	.	.	nil
									Total
									10-66
									<i>Normal</i>
									31-51

Root systems of $U_{\text{even}}(n, \mathbb{C})$ and $U_{\text{odd}}(n, \mathbb{C})$ are given by





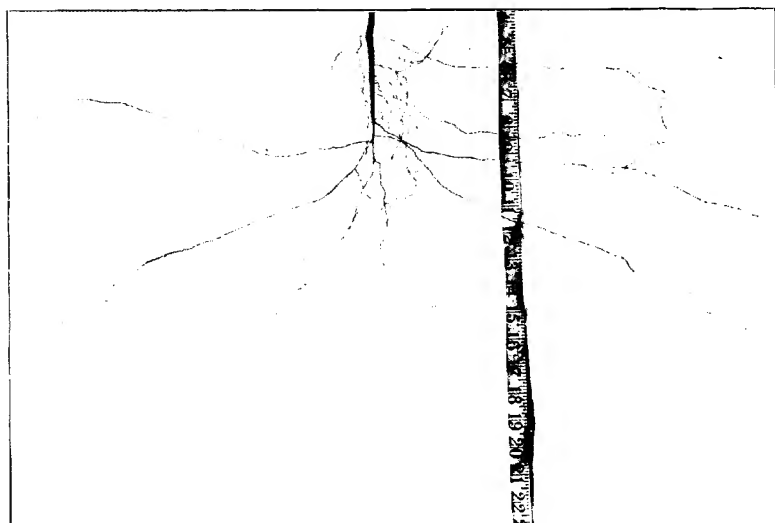
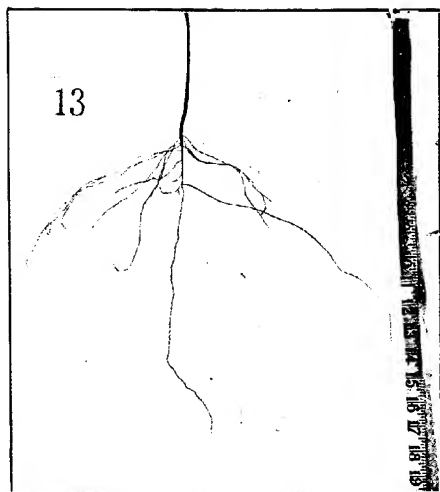


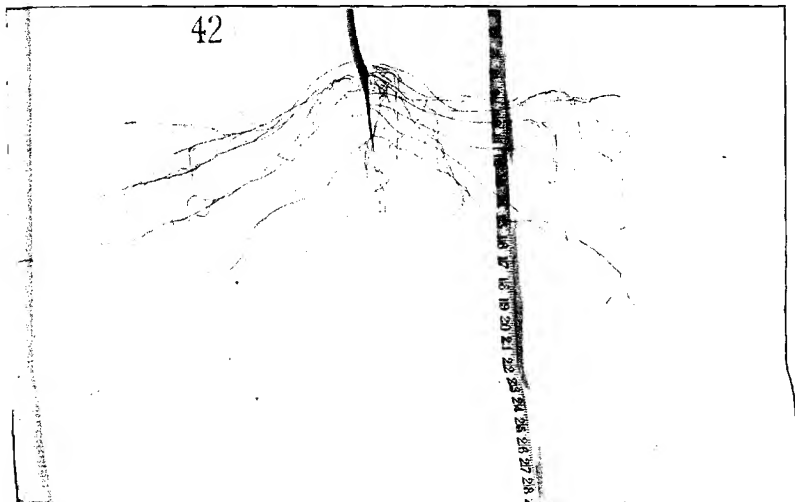
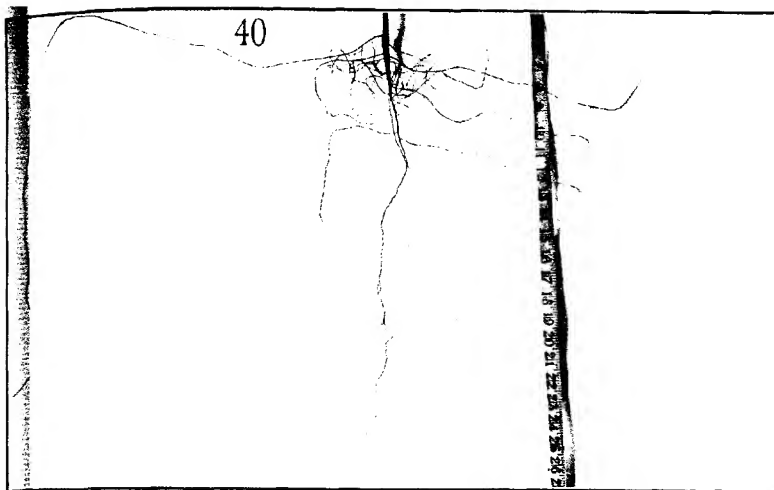


Root system of *Phaseolus vulgaris* L.

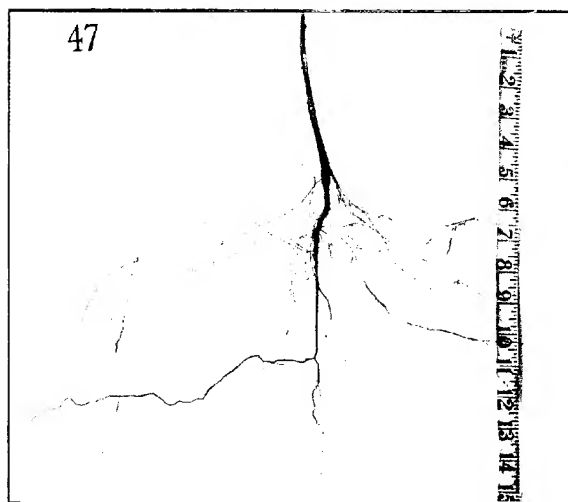
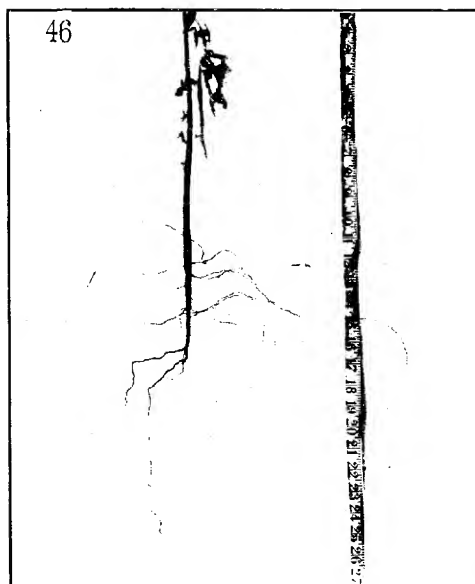


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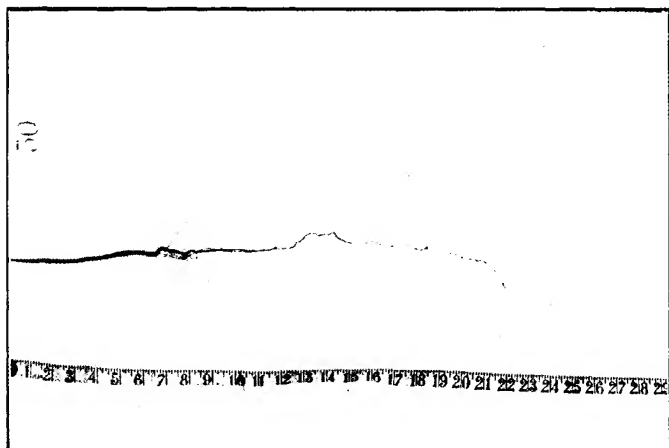
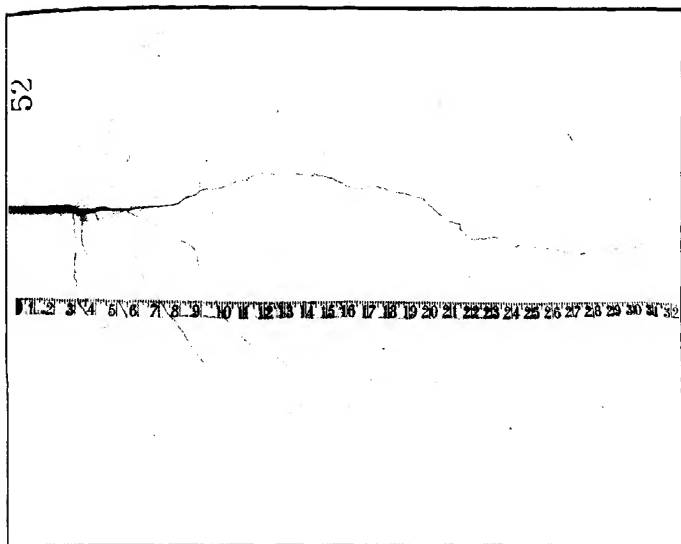




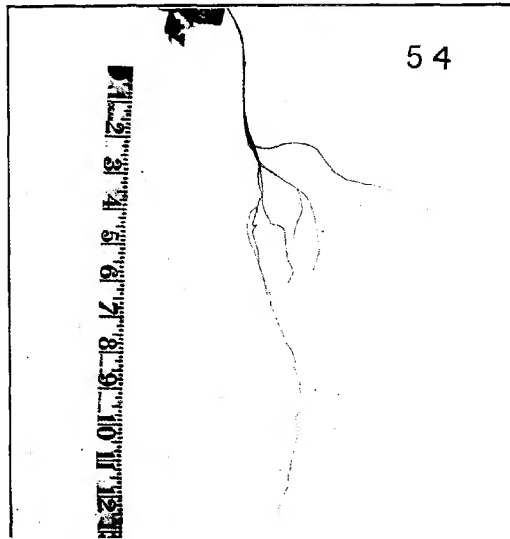
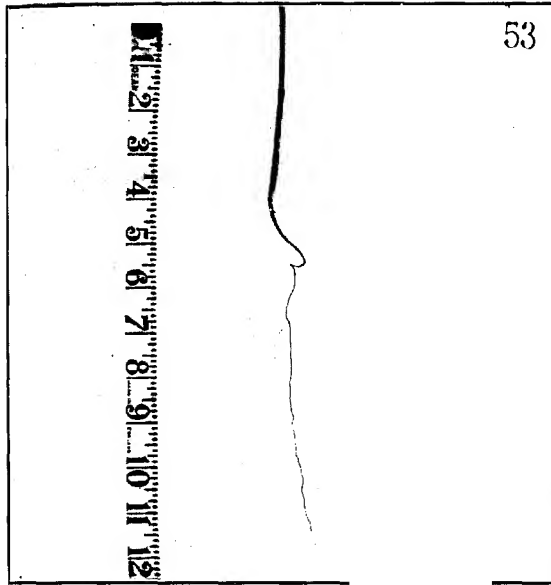
Root systems of Cowhage-American cotton plants, 81 days old; both sown on 15th June.



Root systems of *desi* cotton plants, 81 days old; both sown on 15th June.



Root systems of *Desv.* (No. 50) and Cowpea-American (No. 52) cotton plants, 70 days old; both sown on 7th July.



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